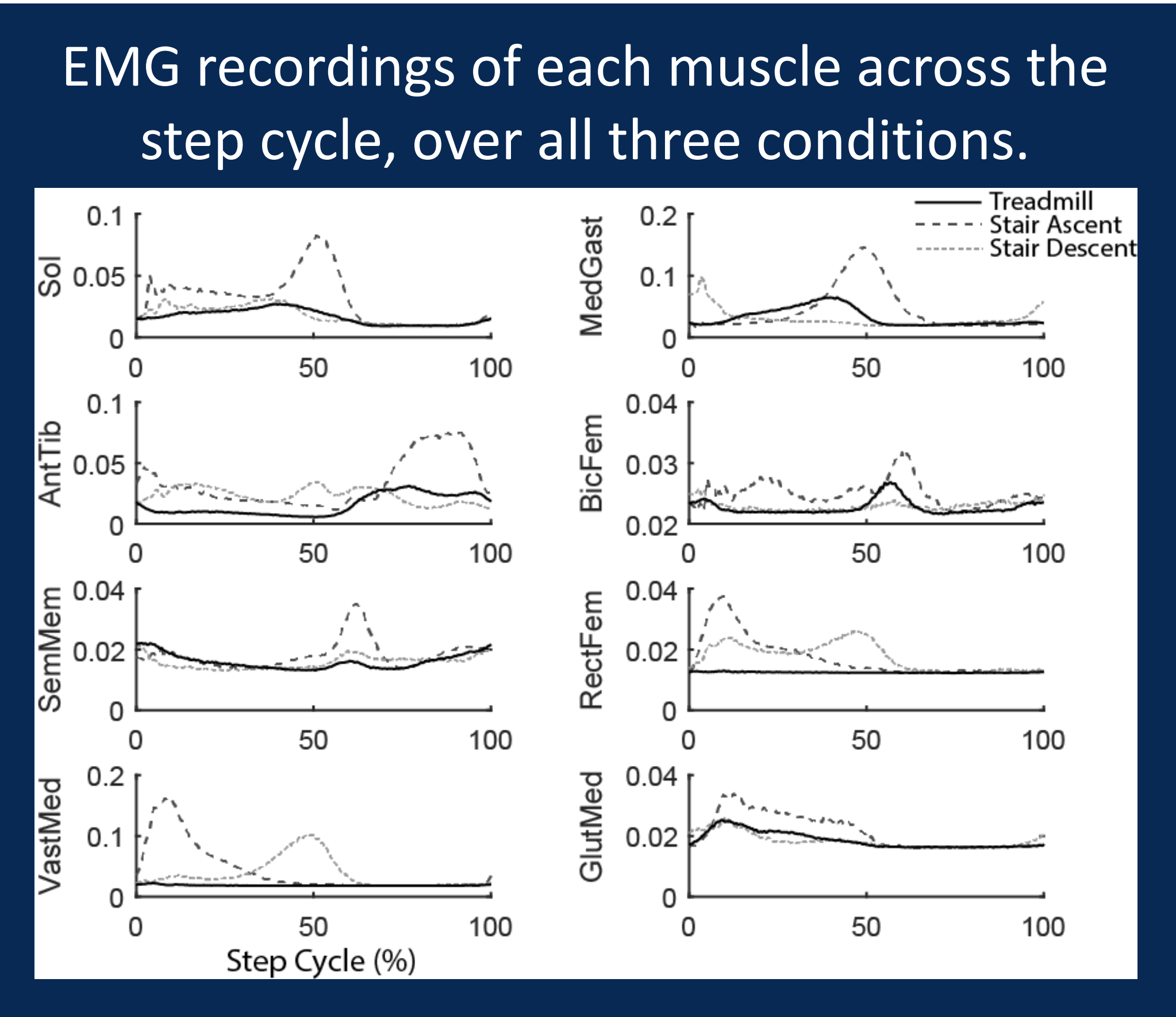


# The vestibular influence on balance control during stair negotiation vs. locomotion

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## Introduction

Stair negotiation accounts for 16% of fall related traumatic spinal cord injuries. The vestibular system plays a crucial role in maintaining balance during human locomotion through its influence over muscles in the lower limb, however, its role during stair negotiation is unknown. The aim of this study was to compare the vestibular contribution to a) stair negotiation versus locomotion and b) stair ascent to stair descent in healthy young participants. We hypothesized that, with cadence held constant, vestibular influence would increase during stair negotiation when compared to locomotion. We also expected the timing of muscle responses to change due to differences in gait patterns.



Average peak coherence and the percent of the step cycle that it occurs, across the three conditions. Presented as: coh, % step cycle

Muscle	Treadmill	Ascent	Descent
Soleus	0.146, 30.217	0.259, 21.118	0.176, 17.702
Medial Gastrocnemius	0.130, 25.466	0.170, 27.640	0.083, 25.683
Semimembranosus	0.056, 42.205	0.095, 29.503	0.032, 49.845
Gluteus Medius	0.158, 42.671	0.112, 45.062	0.099, 56.242

## Methods

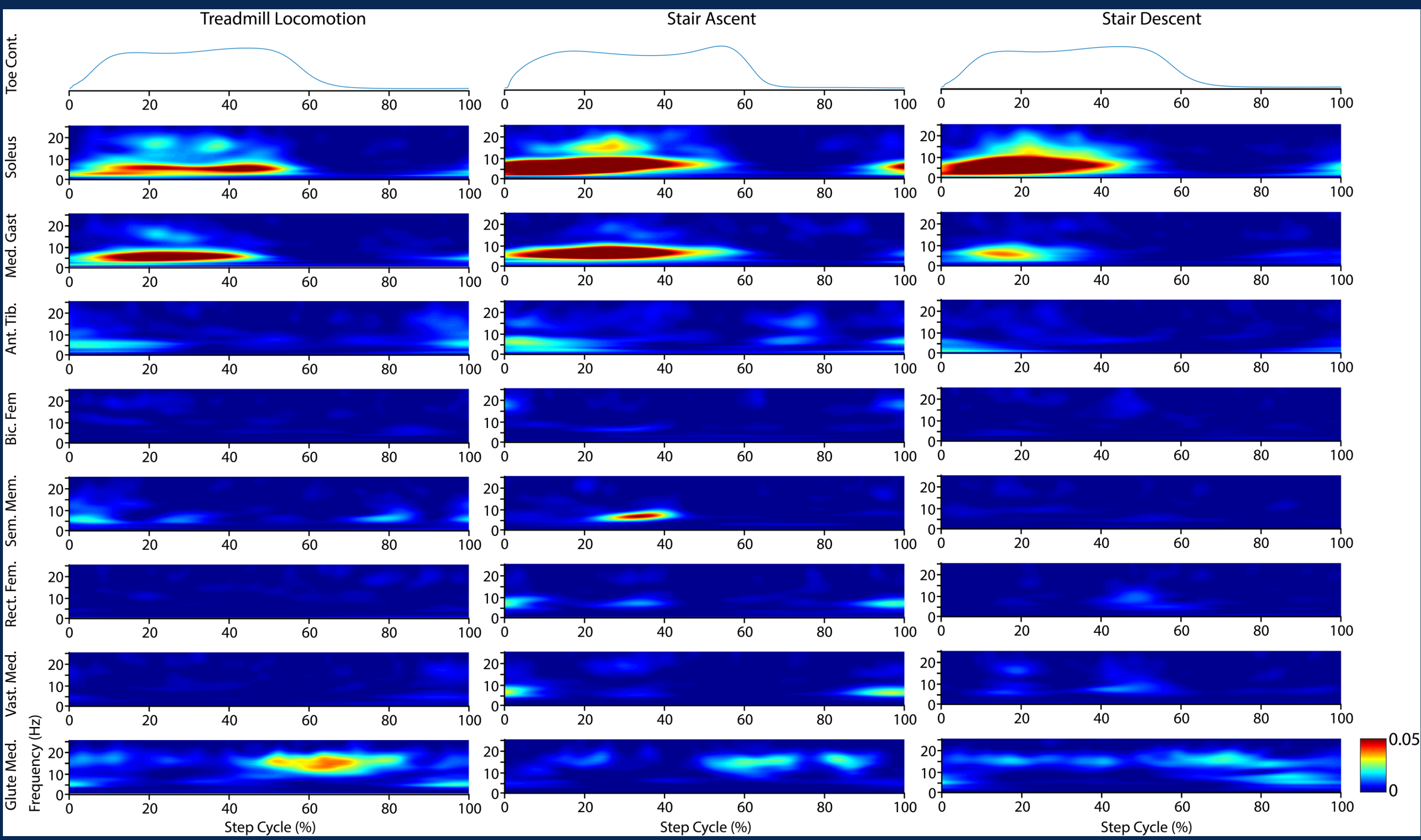
- 10 healthy college aged participants
- Stochastic electrical stimulation - random bandwidth limited (0-25 Hz,  $\pm 5\text{mA}$ )
- Stairs: 9-step staircase over 78 separate trials, at a cadence of 76 steps/min
- Treadmill: 312 steps at a cadence of 76 steps/min and a velocity of 0.4 m/s
- EMG: tibialis ant, soleus, med gastroc, vastus medialis, rectus femoris, semimembranosus, biceps fem, and glute med
- One-way repeated measures ANOVA with SPSS

## Results

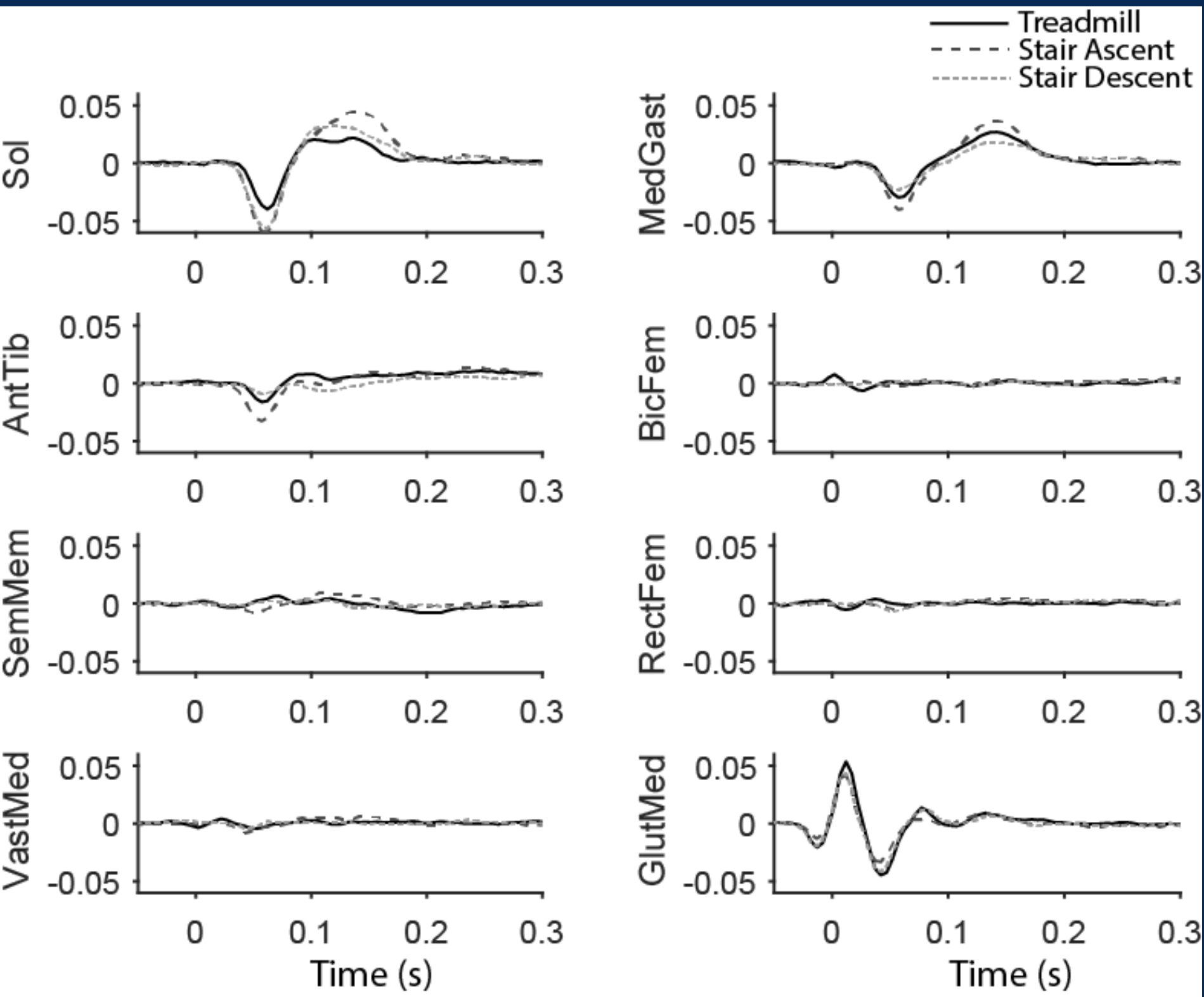
Observed significant differences in the coherence between the three conditions in muscles such as the soleus ( $F_{(2,18)}=21.627$ ,  $P=.000016$ ), medial gastroc ( $F_{(2,18)}=6.538$ ,  $P=.007$ ), and semimembranosus ( $F_{(2,18)}=6.480$ ,  $P=.008$ ). Vestibular modulation of the soleus was significantly lower during locomotion than stair ascent ( $.146 \pm .080$  vs.  $.259 \pm .105$ ,  $p = 0.001$ ), and significantly greater during ascent than descent ( $.176 \pm .076$ ) with  $p = 0.001$ . Significant differences were also seen in modulation timing.

### Peak Coherence over the step cycle

Top row represents the average step cycle for all subjects, followed by the pooled coherence data for the eight muscles recorded. X-axis: % step cycle, y-axis: frequency, z-axis: coherence magnitude. Thresholded by 95% confidence interval in dark blue. Red regions represent the largest coherence.



### Average Cross-Correlation between the vestibular stimulus and muscle activity



Cross-Correlation of Treadmill walking, Stair Ascent, and Stair Descent across time. The y-axis represents correlation magnitude.

## Conclusions

Our findings support the hypothesis that vestibular influence is more prevalent during stair negotiation than during level walking. These findings also suggest that stair ascent produces a greater challenge to balance than stair descent. This could be due to a range of biomechanical factors associated with stair negotiation. We also found the timing of maximum vestibular modulation varies in some muscles, across the three conditions, while gait pattern changes. This study has provided the first in depth look at how the vestibular system influences muscle activity during stair negotiation.

